Detecting and Using Critical Paths at Runtime in Message Driven Parallel Programs

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Motivation

• Critical paths historically have been used important in post-mortem (offline) parallel performance analysis.

• Can they be computed online in message driven parallel languages?

• Is critical path information useful in running parallel HPC programs?
Critical Paths in Parallel Programs

• Existing algorithms for recording critical paths in a hybrid online/offline manner:

  
  
  

• For guiding expert post-mortem performance analysis

• For visualizing parallel program execution to gain understanding
Critical Paths in Message Driven Parallel Programs

- Message Driven Execution (as implemented in Charm++):
  - Tasks invoke methods asynchronously
  - An asynchronous method invocation results in:
    - New local task in queue, or
    - Message sent to remote processor, resulting in new task
Example
Program Activity Graph

- Critical path profiles represent a path through the Program Activity Graph (PAG) composed of computation and messages.
• The PAG can be recorded as a program runs in a distributed graph

• Path weights include computation time, but not message send time
Finding Critical Paths

• Record PAG as program runs

  • Augment each message with:
    • an identifier
    • path length

  • Record maximal incoming path for each task in a table
    • Requires compiler support or code modifications

• Retrieve Critical Path for any task with a backwards traversal
Implementation

• Implemented in the Charm++ runtime system.

• Supports multiple languages:
  • Charm++
  • Structured Dagger
  • Charisma

• Trickiness is in how multiple incoming dependencies are captured.
  • Reductions
  • User maintains knowledge of dependencies satisfied by earlier tasks
  • Language specific dependency mechanisms
Costs of Recording Critical Paths

- Cost of extra 8 bytes in message
- Cost of adding table entries for each task execution

- Microbenchmarks:

- Cost of backwards traversal retrieval: Application Dependent
Use: Automatic Task Priorities

• Automatically Tuning Task Priorities:
  • OpenAtom Application
  • Record critical path for 20 iterations, then switch to new priorities based on observed critical path.

• **10.2% speedup** when prioritizing critical path task types
Uses: Phase Detection

• Critical path is retrieved
• Frequently repeated subpaths are extracted
• Cheap!
Uses: Performance Analysis

- Visualization:
Uses: Filter Performance Data

• Reducing volume of performance analysis data
  • Filter out processors not on critical path
  • Performance analyst only needs to manipulate & view fewer files
Conclusion

- Our Contribution:

  Critical paths can be recorded and used in message driven parallel programs at runtime for tuning message priorities.
Thanks & Questions

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Handling Multiple Input Dependencies

Processor 1
(1,17,7.3)
Processor 2
(2,12,10.5)
Processor 3
Processor 4
(4,19,9.1)

(Source Processor, Source Index, Cummulative Path Duration)

maximum duration incoming dependency = (2,12,10.5)